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Vessels in *Chlorophytum (Liliaceæ)*

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Summary : Vessels in *Chlorophytum* (*Liliaceæ*), like many other members of the family, are probably restricted to roots only. They are formed of elements having either oblique or transverse end walls with simple perforation plates and variously sculptured lateral secondary walls. Vessel elements vary in length and breadth in different species. Most commonly they are cylindrical in the protoxylem and 9-14-angled in the metaxylem. Although these features of vessel elements are fairly constant for a species, due to their continuous and overlapping nature in various taxa, they cannot be employed for taxonomic purposes at specific level. They have been used here to classify the investigated species of the genus into two main groups. It is interesting to note that these groups show definite correlation with chromosome numbers together with habitat, habit and duration of aerial shoot.

Résumé : Comme chez de nombreuses autres Liliacées, les vaisseaux, dans le genre *Chlorophytum*, semblent n'exister que dans les racines. Leurs éléments ont des cloisons transversales ou obliques, à perforations simples, et des parois secondaires latérales diversement ornées. La longueur et la largeur des éléments de vaisseaux varient chez les différentes espèces ; le plus souvent, ils sont cylindriques dans le protoxylème et à 9-14 angles dans le métaxylème. Les caractères des éléments de vaisseaux sont constants dans chaque espèce, mais leur variation est continue et montre des recouvrements d'une espèce à l'autre ; on ne peut pas les utiliser dans un but taxonomique au niveau spécifique. On les utilise ici pour classer les espèces étudiées en 2 grands groupes. Il est intéressant de noter que dans ces groupes, on observe des corrélations entre les nombres chromosomiques, l'habitat, le port et la durée de vie de la pousse aérienne.

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INTRODUCTION

Features of wood anatomy in general and those of vessels in particular, have been employed at all levels of taxonomic hierarchy and phylogeny. Their use has been particularly significant in the dicotyledonous taxa. Less commonly they have been employed in the taxonomy and phylogeny of the monocotyledons. Cheadle, for instance, considered the occurrence (1942) as well as their origin and specialization (1943*a*) in his earlier publications and later (1943*b*, 1944) amplified the observations on the specialization of vessels in the late metaxylem of various organs in the monocotyledons. In these early observations (Cheadle, 1943*a*), it has been pointed out that the pitting of the lateral walls of the tracheal elements is so uniform that it cannot serve as a diagnostic character. Tomlinson (1961) supported this view for the *Palmæ* and utilized other data for taxonomic consideration of

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Aphyllanthes and *Eriocaulaceæ* (1965). Bailey (1944) and later on Cheadle & Tucker (1961) believed that the data on vessels can be used most effectively in nagating putative relationships. Cheadle, in his later publications tried to utilize this data for taxonomic purposes in the *Gramineæ*, *Cyperaceæ*, *Juncaceæ* and *Restionaceæ* (1955, 1960), *Iridaceæ* (1963), *Hæmodorales* (1968), *Amaryllidaceæ* (1969), *Pontederiaceæ*, *Ruscaceæ*, *Smilacaceæ* and *Trilliaceæ* (1970) and *Liliaceæ* (Cheadle & Kosakai, 1971). In this last paper the authors admitted that the amount and distribution of secondary wall thickening were not carefully analysed by them and further indicated two " generally different kinds " in the lateral walls.

The present investigation was undertaken in order to assess taxonomic value of lateral wall thickening patterns in the metaxylem vessels of liliaceous genus *Chlorophytum*.

MATERIAL AND METHODS

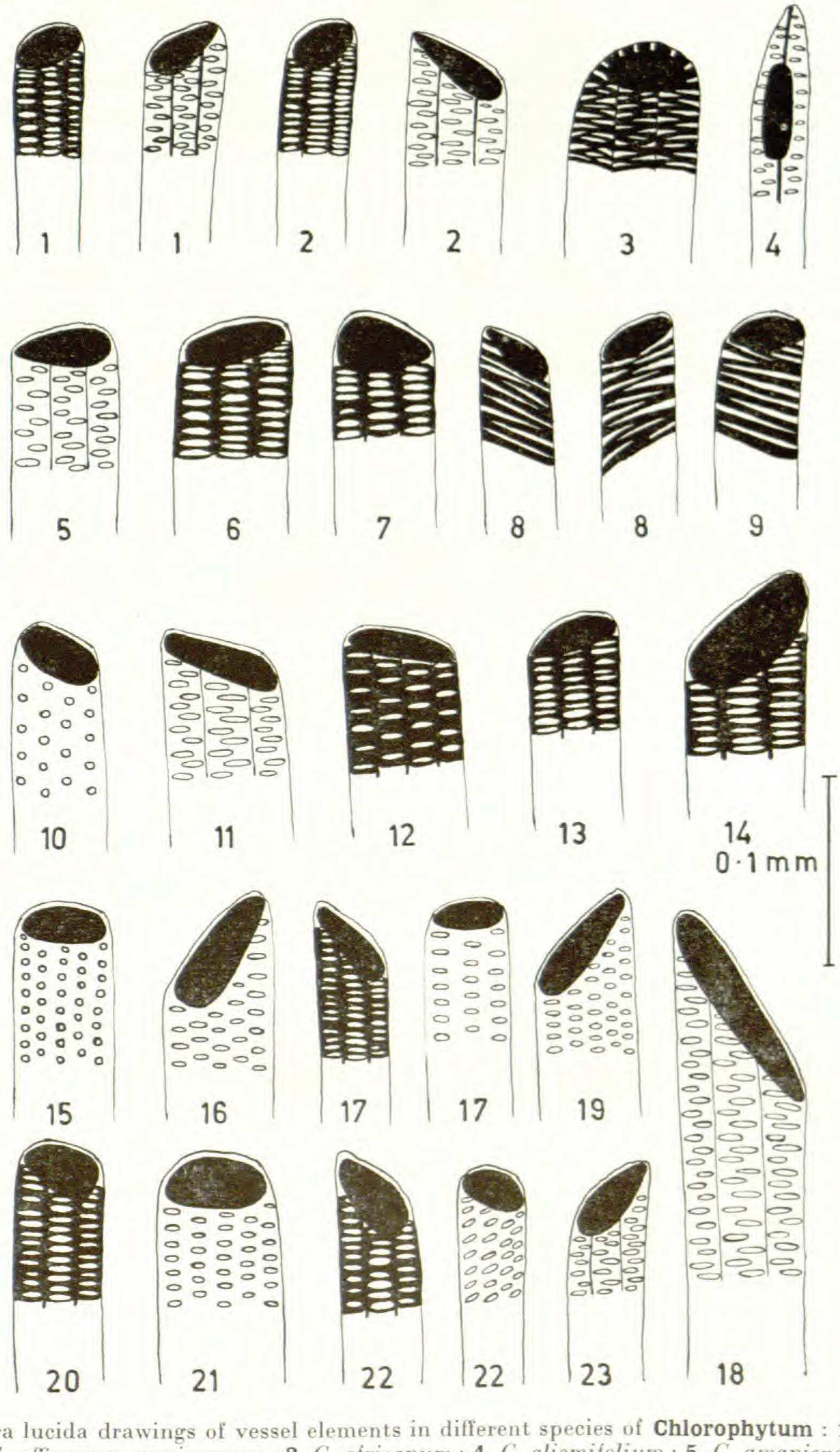
Root fragments of about 200 herbarium as well as living specimens of about 51 tropical African and 11 Indian taxa of *Chlorophytum* (these include a few specimens of section *Dasystachys* and one specimen of *Anthericum*) were macerated using a mixture of HNO_3 (2 %) and $K_2Cr_2O_7$ (5 %) solutions. The vessel elements were stained with aqueous saffranin (1 %), dehydrated, and mounted in Canada Balsam using routine procedure. All measurements and camera lucida drawings were taken at × 200 magnification while the photomicrographs were taken at × 400 magnification. The slides have been deposited in the museum of this department. Observations have been confined to the metaxylem (broadest) elements.

OBSERVATIONS

All the root fragments of about 51 African and 11 Indian taxa revealed presence of vessels. Aerial parts of the Indian taxa indicated total absence of vessels. Since only root fragments of African taxa were available for present investigation, the presence or absence of vessels in their aerial parts could not be ascertained. Certain African species (*C. comosum*, *C. laxum*, *C. macrophyllum*, *C. suffruticosum* and *C. tuberosum*) grown in the departmental botanic garden, also did not indicate presence of vessels in parts other than the roots.

Vessel elements vary in their length and breadth in different species. The shortest elements (0.48 mm long) were observed in *C. africanum* (Pl. 1, *3*) while the longest ones (3.22 mm long) were noted in *C. papillosum* (Pl. 2, *30*). Similarly, the narrowest elements (0.024 mm broad) have been recorded in *C. alismifolium* (Pl. 1, *4*) while the broadest ones (0.102 mm broad) were observed in *C. viscosum* (Pl. 2, *50*). In spite of this range in different species, it appears that the size of mature elements is more or less constant for a given species. The average size of vessel elements for the genus is 1.8 × 0.06 mm. Most commonly the vessels are cylindric in the protoxylem and 9-14-angled in metaxylem.

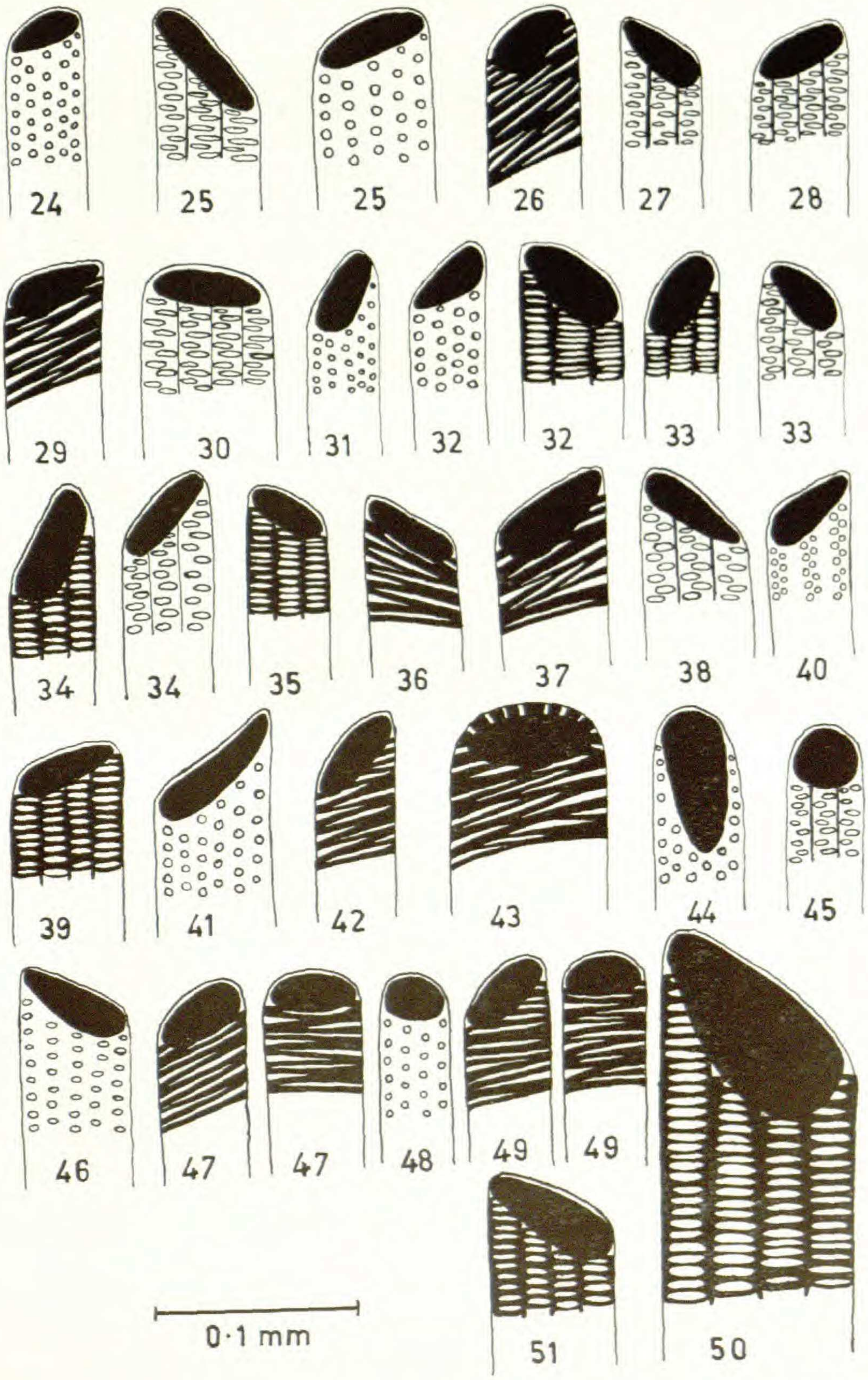
All the investigated taxa revealed vessel elements with uniformly simple perforation plates in their end walls and the latter are either oblique or variously truncated. The single perforation, in most of the elements, is as broad as the end wall itself. Occasionally, perforation is smaller in diameter than that of the end wall (Pl. 1, *3*, *22* ; 2, *26*). But in no case, more than one perforation or the scalariform end wall was noted in the metaxylem. Oblique end walls with scalariform plates occur in protoxylem elements of certain species.



Pl. 1. — Camera lucida drawings of vessel elements in different species of **Chlorophytum** : **1**, *C. affine* var. *affine* ; **2**, *C. affine* var. *curviscapum* ; **3**, *C. africanum* ; **4**, *C. alismifolium* ; **5**, *C. amaniense* ; **6**, *C. andongense* ; **7**, *C. arcuatoramosum* ; **8**, *C. barkeri* ; **9**, *C. bifolium* ; **10**, *C. blepharophyllum* ; **11**, *C. campanulatum* ; **12**, *C. carsonii* ; **13**, *C. collinum* ; **14**, *C. colubrinum* ; **15**, *C. comosum* ; **16**, *C. filipendulum* ; **17**, *C. fischeri* ; **18**, *C. gallabatense* ; **19**, *C. geophilum* ; **20**, *C. humifusum* ; **21**, *C. inopinum* ; **22**, *C. inornatum* ; **23**, *C. lancifolium*.

TABLE I. — Details of vessel elements in *Chlorophytum*.

NAME OF SPECIES	SCULPTURING PATTERN OF VESSEL ELEMENTS	AVERAGE LENGTH AND BREADTH OF VESSEL ELEMENTS (mm)	CHROMOSOME NUMBER (2n)	HABITAT
1. *C. affine* var. *affine*	Sc, Sc-P	1.5 × 0.050	—	Semi-arid
2. *C. affine* var. *curviscapum*	Sc, Sc-P	0.89 × 0.060	—	Humid
3. *C. africanum*	Sp-Sc	0.75 × 0.072	—	Humid
4. *C. alismifolium*	Sc-P	0.99 × 0.030	16	Humid
5. *C. amaniense*	Sc-P	1.59 × 0.033	—	Humid
6. *C. andongense*	Sc	1.29 × 0.075	—	General
7. *C. arcuatoramosum*	Sc	0.99 × 0.070	—	Humid
8. *C. barkeri*	Sp	1.86 × 0.040	—	Semi-arid
9. *C. bifolium*	Sp	0.87 × 0.045	—	Semi-arid
10. *C. blepharophyllum*	P	1.62 × 0.048	—	Humid
11. *C. campanulatum*	Sc-P	1.25 × 0.041	—	Humid
12. *C. carsonii*	Sp-Sc	1.50 × 0.084	—	Semi-arid
13. *C. collinum*	Sc	1.23 × 0.057	—	Humid
14. *C. colubrinum*	Sc	1.02 × 0.057	—	General
15. *C. comosum*	P	2.16 × 0.069	28	Humid
16. *C. filipendulum*	P	1.50 × 0.066	—	Humid
17. *C. fischeri*	P	1.38 × 0.055	—	Humid
18. *C. gallabatense*	Sc-P, P	1.80 × 0.081	—	Humid
19. *C. geophilum*	P	1.71 × 0.069	—	Humid
20. *C. humifusum*	Sc	1.35 × 0.063	—	Humid
21. *C. inopinum*	P	1.41 × 0.063	—	Humid
22. *C. inornatum*	P	0.90 × 0.051	14	Humid
23. *C. lancifolium*	Sc-P	0.81 × 0.036	—	Semi-arid
24. *C. laxum*	P	1.23 × 0.033	14	General
25. *C. macrophyllum*	Sc-P, P	1.92 × 0.084	—	Humid
26. *C. marginatum*	Sp-Sc	1.41 × 0.072	—	Semi-arid
27. *C. micranthum*	Sc-P	1.23 × 0.045	—	Humid
28. *C. miserum*	Sc-P	1.20 × 0.072	—	Humid
29. *C. nidulans*	Sp-Sc	1.77 × 0.045	—	Humid
30. *C. papillosum*	Sc-P	2.93 × 0.090	—	Humid
31. *C. pauper*	P	1.83 × 0.054	—	Humid
32. *C. pilosissimum*	P	1.38 × 0.039	—	Humid
33. *C. polystachys*	Sc-P	1.44 × 0.068	—	Humid
34. *C. pleiostachyum*	Sc, Sc-P, P	1.36 × 0.036	—	Humid
35. *C. pubirachis*	Sc	1.41 × 0.051	—	Humid
36. *C. pusillum*	Sp-Sc	1.02 × 0.039	—	Semi-arid
37. *C. rivæ*	Sp-Sc	0.90 × 0.075	—	Semi-arid
38. *C. schimperi*	Sc-P	1.38 × 0.060	—	Arid
39. *C. silvaticum*	Sc	0.79 × 0.051	—	Humid
40. *C. sparsiflorum*	P	1.56 × 0.075	—	Semi-arid
41. *C. stenopetalum*	P	2.43 × 0.078	—	Semi-arid
42. *C. tenellum*	Sp-Sc	0.78 × 0.039	—	Humid
43. *C. tenuifolium*	Sp-Sc	1.80 × 0.081	—	Humid
44. *C. tetraphyllum*	P	1.65 × 0.045	—	Arid
45. *C. tordense*	Sc-P	1.14 × 0.051	—	Humid



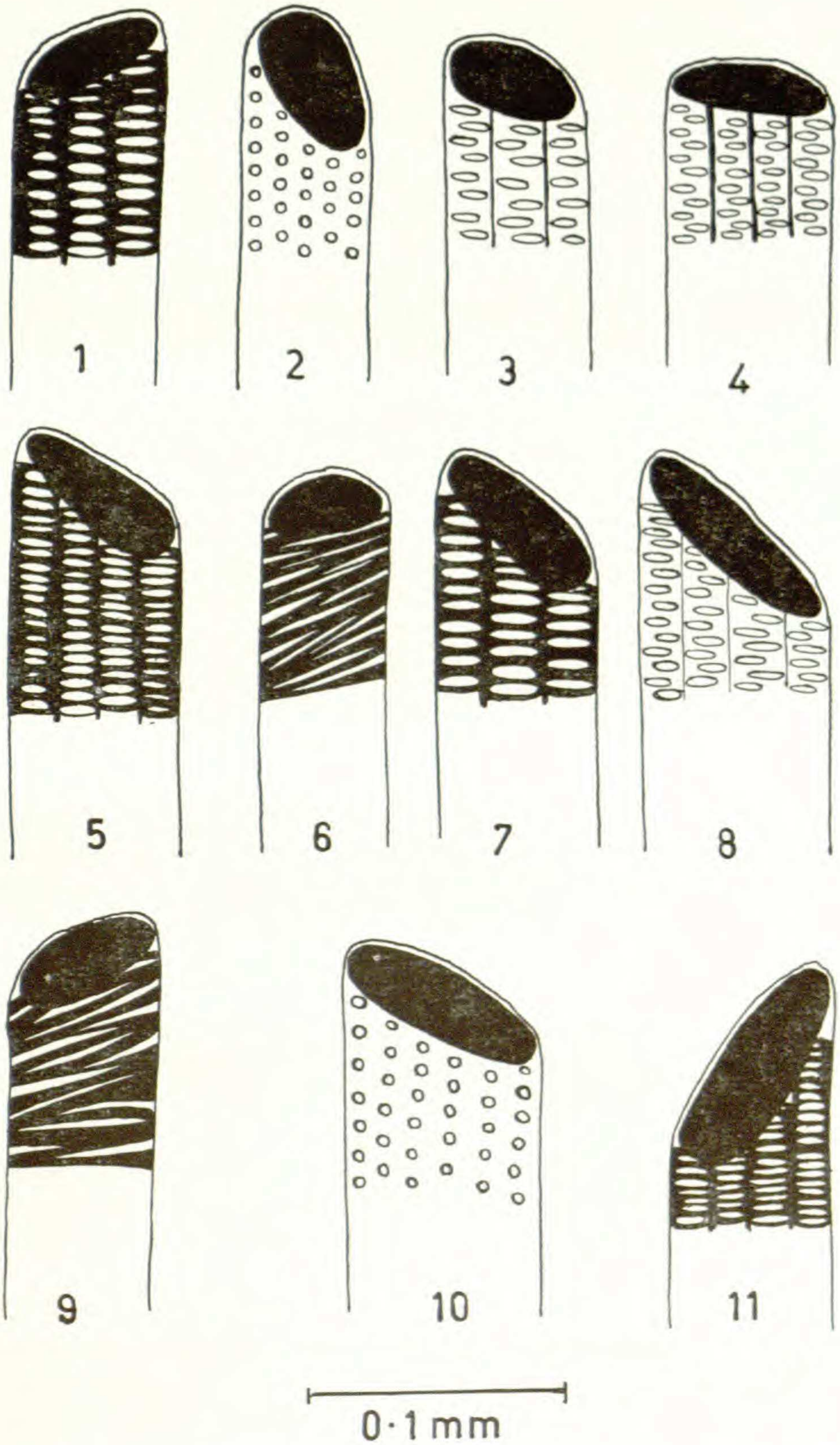
Pl. 2. — Camera lucida drawings of vessel elements in different species of **Chlorophytum** : **24**, *C. laxum* ; **25**, *C. macrophyllum* ; **26**, *C. marginatum* ; **27**, *C. micranthum* ; **28**, *C. miserum* ; **29**, *C. nidulans* ; **30**, *C. papillosum* ; **31**, *C. pauper* ; **32**, *C. pilosissimum* ; **33**, *C. polystachys* ; **34**, *C. pleiostachyum* ; **35**, *C. pubirachis* ; **36**, *C. pusillum* ; **37**, *C. rivæ* ; **38**, *C. schimperi* ; **39**, *C. silvaticum* ; **40**, *C. sparsiflorum* ; **41**, *C. stenopetalum* ; **42**, *C. tenellum* ; **43**, *C. tenuifolium* ; **44**, *C. tetraphyllum* ; **45**, *C. tordense* ; **46**, *C. trachycarpum* ; **47**, *C. tuberosum* ; **48**, *C. vestitum* ; **49**, *C. viridescens* ; **50**, *C. viscosum* ; **51**, *C. zavattari*.

TABLE I (Contd.)

NAME OF SPECIES	SCULPTURING PATTERN OF VESSEL ELEMENTS	AVERAGE LENGTH AND OF BREADTH VESSEL ELEMENTS (mm)	CHROMOSOME NUMBER (2n)	HABITAT
46. *C. trachycarpum*	P	1.95 × 0.057	—	Humid
47. *C. tuberosum*	Sp-Sc	1.68 × 0.081	16	Semi-arid
48. *C. vestitum*	P	1.59 × 0.042	—	Humid
49. *C. viridescens*	Sp-Sc	0.84 × 0.042	—	Semi-arid
50. *C. viscosum*	Sc	1.56 × 0.087	—	Humid
51. *C. zavattari*	Sc	1.50 × 0.080	—	Semi-arid
		INDIAN TAXA		
1. *C. bharuchæ*	Sc	1.85 × 0.090	16	Semi-arid
2. *C. glaucoides*	Sc-P	1.75 × 0.070	42	Humid
3. *C. glaucum*	Sc-P	2.30 × 0.060	42	Humid
4. *C. indicum*	Sc-P	0.98 × 0.057	28	Semi-arid
5. *C. laxum*	Sp	1.15 × 0.045	16	Semi-arid
6. *C. nepalense*	Sc	1.65 × 0.090	56	Humid
7. *C. nimmonii*	Sc-P	1.80 × 0.075	42	Humid
8. *C. tuberosum*	Sp	1.25 × 0.045	16	Semi-arid
		AFRICAN TAXA GROWN IN THE DEPARTMENTAL GARDEN		
1. *C. comosum*	P	1.75 × 0.060	28	
2. *C. macrophyllum*	P	1.30 × 0.075	56	
3. *C. suffruticosum* (= *Anthericum suffruticosum*)	Sc	1.15 × 0.080	32	

Thickening due to secondary wall or sculpturing of the lateral walls revealed two main patterns which have been termed here as 1) Spiral, and 2) Scalariform or Pitted. The boundaries between these patterns appear to be well defined although certain elements with spiral pattern do show a tendency towards scalariform thickening. The second pattern revealed a mixture of scalariform and pitted thickening in a large number of taxa. It was, therefore, necessary to classify these patterns into five groups, viz. 1) Spiral (Sp) ; 2) Spiral-Scalariform (Sp-Sc) ; 3) Scalariform (Sc) ; 4) Scalariform-Pitted (Sc-P) and 5) Pitted (P) (see Plate 4). Table I shows distribution of these patterns in various taxa together with other relevant data. All the vessel elements are illustrated in Plates 1, 2, and 3. It is evident from the Table I that about 50 % of the species exhibit only a single pattern, while others show more than one sculpturing pattern. With the notable exception of *C. laxum* none of the taxa showed all the five patterns or a mixture of two main patterns.

The sculpturing due to secondary walls becomes disrupted when two or more vessels develop side by side. A large number of such pairs were observed in *C. blepharophyllum*,



Pl. 3. — Camera lucida drawings of vessel elements in differents species of **Chlorophytum** : **1**, *C. bharuchæ* ; **2**, *C. comosum* ; **3**, *C. glaucoides* ; **4**, *C. glaucum* ; **5**, *C. indicum* ; **6**, *C. laxum* ; **7**, *C. nepalense* ; **8**, *C. nimmonii* ; **9**, *C. tuberosum* ; **10**, *C. macrophyllum* ; **11**, *C. suffruticosum* (= *Anthericum suffruticosum*).

C. comosum and *C. filipendulum*. Elements of these paired vessels showed scalariform pattern along their sides of contact with each other while the normal pitted pattern was noted on the remaining surface (Pl. 4, *15*).

DISCUSSION

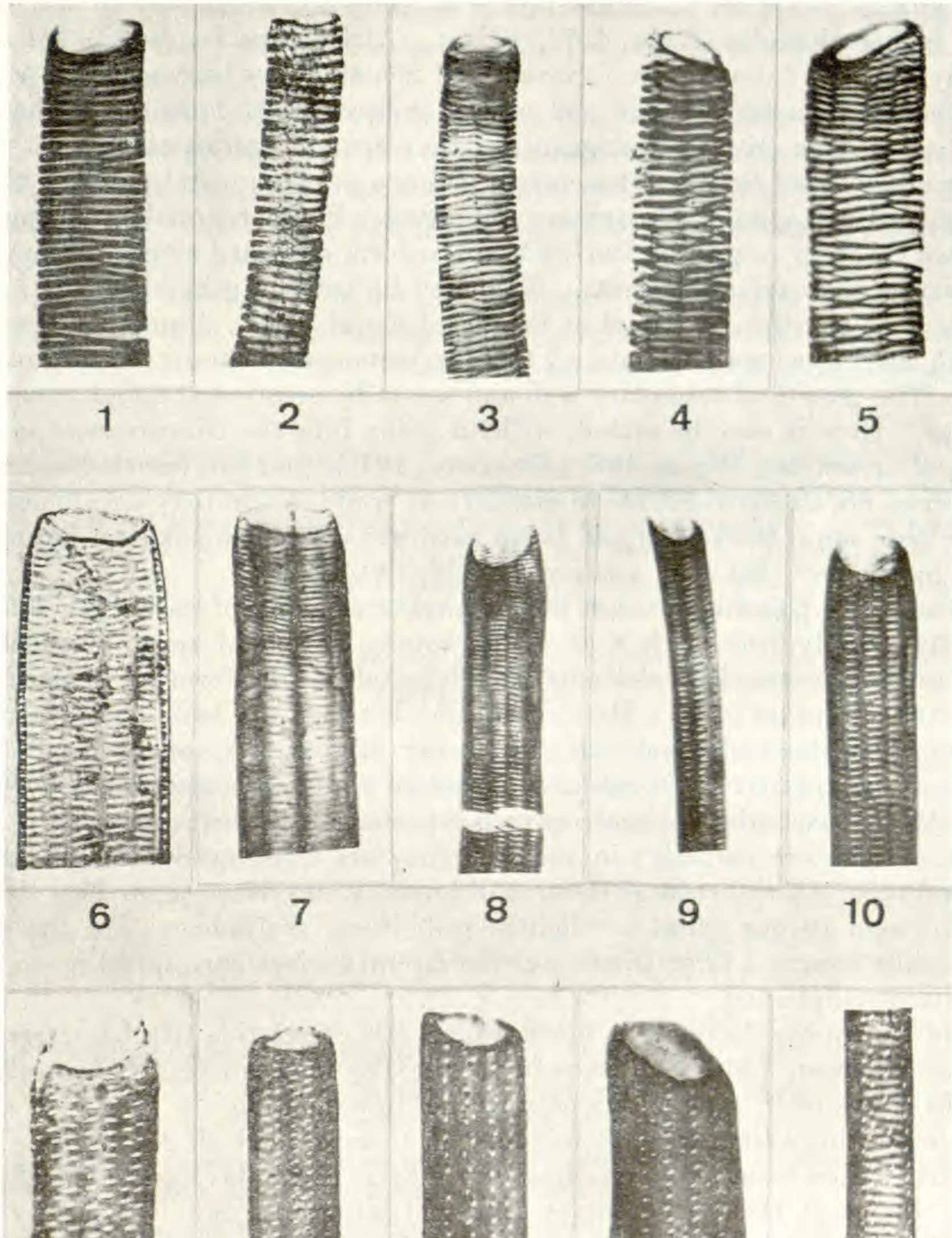
Vessels in the tribe *Asphodeleæ* were first observed in some details by CHEADLE & KOSAKAI (1971) who recorded their presence in roots of all the members investigated by them. Vessels were observed also in stems of 4 genera and 5 species of the tribe by these authors. However, in *Chlorophytum*, vessels have not been recorded so far in rhizome, stem or leaf.

CHEADLE & KOSAKAI (*loc. cit.*) had only one species of *Chlorophytum*, viz. *C. comosum*, for their observation. These authors have noted more or less oblique end walls with a single large perforation and about ten smaller perforations in this species (CHEADLE & KOSAKAI : 324, *tab. 7*, 1971). They have indicated numerous pits in the oblique end walls. The present study does not confirm this nature of end wall in *C. comosum* (see Pl. 1, *15* and Pl. 3, *2*). Instead, more or less truncated end walls with uniformly single large perforation without any pits occur in both, African as well as Indian, specimens. In fact, none of the species investigated, indicated scalariform plates in the metaxylem. They have been observed in vessel elements of protoxylem or early metaxylem of certain species. In general, therefore, as indicated by the above authors, vessels in *Chlorophytum* are highly advanced.

BAILEY (1944) and later on CHEADLE and his associates have considered the pattern of end walls alone, for phylogenetic interpretations or deciding the degree of advancement. It appears that this criterion is useful at generic or higher levels but at specific level and below, the end wall pattern is more or less constant and is of little use in determining advancement index. It can be said from the present study, that at specific and infraspecific levels, the pattern of secondary wall thickening is more useful. Although patterns indicated here for various taxa are not diagnostic at specific levels, they indicate two main groups, viz., species with spiral (Sp) or slightly scalariform (Sp-Sc) thickening and those with scalariform to pitted (Sc, Sc-P, P) thickening.

In *Chlorophytum*, there are two groups of species ; in one the aerial shoot lives only for a month or two and in the other it may continue to grow for four to six months or may be perennial. It has also been noted that species from the first group mostly have $2n = 16$ (or $x = 8$) chromosomes and those from the second group have $2n = 14, 28, 42, 56$ or 84 (or $x = 7$) chromosomes, wherever the latter is known. In other words, the species with $x = 8$ are known at diploid level only while those with $x = 7$ may be at diploid as well as various polyploid levels (BALDWIN & SPEESE, 1951 ; MATHEW & THOMAS, 1974 ; NAIK, 1976, 1977*a*, 1977*b*, 1979, 1980 ; PAHUJA & KUMAR, 1969 ; SATO, 1942 ; SHERIFF & CHENNAVEERAIAH, 1972, 1975). The polyploids with $x = 8$ have been recorded in the closely related genus *Anthericum* L. (POPOVA & CESCHMEDJIEV, 1978 ; NAIK & NIRGUDE, unpublished data).

The distribution of Indian species is well known and it may be said in a nut shell that those with $2n = 16$ (or $x = 8$) are more or less widely distributed in semi-arid regions while



Pl. 4. — Photomicrographs of certain vessel elements showing various sculpturing patterns on lateral walls : **1**, *C. tuberosum* ; **2**, *C. barkeri* ; **3**, *C. viridescens* ; **4**, *C. tenellum* ; **5**, *C. tenuifolium* ; **6**, *C. carsonii* ; **7**, *C. andongense* ; **8**, *C. affine* var. *curviscapum* ; **9**, *C. affine* var. *affine* ; **10**, *C. sylvaticum* ; **11**, *C. glaucum* ; **12**, *C. comosum* ; **13**, *C. macrophyllum* ; **14**, *C. blepharophyllum* ; **15**, *C. filipendulum*.

the others with $2n = 14, 28, 42, 56$ or 84 (or $x = 7$) are rather confined to the more humid climate of higher altitudes (NAIK, 1976, 1977*a*). African species distributed in Uganda, North Kenya, North Zaire, North Tanzania and Somalia may be considered as inhabiting semi-arid regions in a broad sense and others occupy humid localities. The exceptions may well be noted on critical assessment but they are not known at present.

It is generally held that vessel members indicate developmental patterns of secondary walls from annular to spiral to scalariform and pitted. Further, annular and spiral thickening is known to occur in protoxylem while scalariform or pitted thickening is a characteristic pattern of metaxylem elements. This may be true, in general, for all those angiosperms which have either perennial or long-lived aerial parts. But in *Chlorophytum*, the species with short lived aerial shoots, all the developmental patterns of sculpturing are not exhibited. The growth of secondary wall appears to be arrested at spiral or slightly scalariform stage. Here it may be stated, without going into the controversies of definitions of proto- and metaxylem (ESAU, 1943 ; CHEADLE, 1944), that the vessel elements observed in these species are clearly referable to metaxylem, while the protoxylem elements are with annular or loose spiral thickening and much narrower. Their metaxylem nature is further confirmed by the fact that they are incapable of stretching.

It is also worth pointing out that the metaxylem elements of the species with long lived aerial shoots or polyploids with $x = 7$, are totally devoid of spiral thickening. Here, even the earliest metaxylem elements are definitely scalariform or scalariform-pitted.

Thus, there appears to be a close correlation between the basic chromosome number, ecology, duration of aerial shoot and sculpturing pattern of secondary walls.

The main two patterns of sculpturing discussed above were also noted by CHEADLE & KOSAKAI (1971) but both the kinds have been referred by them as " pits ". According to them, these pits are variable ; in one kind they are transversely elongate to irregular in shape and occupy a rather large fraction of lateral wall surface (their Figs. 16, 61 to 68). These correspond to our spiral or slightly scalariform sculpturing. In the second, the secondary walls occupy a large fraction of the lateral surface corresponding to our scalariform to pitted sculpturing.

Certain exceptions have been noted where the correlation of characters mentioned above, does not exist. Although some of these exceptions can be satisfactorily explained on the basis of available data, others need further investigation.

Most interesting exception is to be found in *C. laxum* (Pl. 2, *24* ; 3, *6*). This species is widely distributed from Africa to Middle east Asia, India, Java and Australia (HOOKER, 1892). In India, at least, it occupies semi-arid situations and is typically short-lived species. It has $2n = 16$ chromosomes (NAIK, 1976) and the vessel elements have spirally thickened secondary walls. Thus the above correlation is complete. But the African population is different in many respects. It has $2n = 14$ chromosomes (BALDWIN & SPEESE, 1951) and the vessels have pitted pattern of secondary walls. This latter population has been considered to be derivative of the ancient unknown population with $2n = 16$ chromosomes by deletion of one of the bivalents (NAIK, 1976). The present study also confirms the advanced or derived nature of populations with $2n = 14$ chromosomes.

Other exceptions are to be found in *C. alismifolium* and *C. bharuchæ*. Both these species have $2n = 16$ chromosomes (BALDWIN & SPEESE, 1951 ; NAIK, 1974, 1977*b*) but their vessel elements have either scalariform or scalariform-pitted sculpturing of secondary walls. This may be attributed to the humid habitat in case of the former and to the robust habit in case of the latter. Both these species may be taken to be relatively advanced in a group with $x = 8$ chromosomes.

A solitary instance of polyploidy in this group has been recently studied. *Anthericum suffruticosum* (Bak.) Milne-Redhead (= *Chlorophytum suffruticosum* Bak.) has $2n = 32$ chromosomes (Naik & Nirgude, unpublished data) and is noted here to have scalariform pattern of sculpturing of secondary wall (Pl. 3, *11*). This may be regarded as an advancement, concomitant with tetraploidy.

In spite of these exceptions, it may be presumed that the correlation of characters mentioned above, might be expected in the rest of the species where the data on chromosome numbers is not available at present. This presumption, however, must be supplemented with further investigation.

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